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The new norm for gold miners and how change in mine waste management could help

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Abstract

The gold mining industry has been out of favour with institutional investors in the last decade as major mergers, acquisitions and other shapes of restructuring took place right at the height of the commodity cycle, leaving the gold mining companies laden with debt. At the same time, institutional investors have observed a new trend in heightened emphasis on environmental, social and governance (ESG) related matters. As institutional investors have a lot of influence on gold mining companies through their significant majority shareholding positions, alignment with their ESG investment criteria is critical to gold mining companies for financial sustainability. This paper explores the ways alternative mine tailings management practices could help gold miners align with institutional investors' ESG criteria. Maximising the application of thickened tailings, paste, filtered tailings, and underground and open pit backfill directly translates into reductions in land use and hazardous waste, increased water efficiency, and potential increases in energy efficiency; hence, reduced GHG emissions. A reduced waste footprint has indirect benefits related to other ESG aspects like biodiversity and potential social impact. The paper provides a qualitative to semi-quantitative assessment of the impact on lifecycle return on investment in these seemingly more elaborate and costly mine waste management approaches by improving ESG scores and enhancing the chances for access to more favoured and affordable financing.

Keywords: *ESG, water use, land use, mine tailings*

1 Introduction

Throughout history, the primary function of gold has been the storage of value. In 2020, use of gold for applications that involved physical consumption (dentistry, semiconductors and technology) was only 8.1% of the total global demand (World Gold Council 2021). Despite the collapse of the Bretton Woods system in 1973, gold continued to play an important role in the reserve holding for major economic powers (Ghosh 2021). The top 40 official gold holdings reported in September 2021 totalled 33,202 tonnes. The USA ranked first with 25% of the total top 40 holdings, followed by Germany with 10% and The International Monetary Fund with 9% (World Gold Council 2021).

Investors use gold for diversification and hedging, and as a safe haven in their portfolios. The effectiveness of these strategies varied over time depending on the state of the global economy and the level of uncertainty (Bredin et al. 2015, 2017; Baur & Lucey 2010).

Investment in gold mining equities and its relationship with investment in gold have been studied by many researchers, among them Blose & Shieh (1995), Batten et al. (2017), Dar et al. (2019), Shahzad et al. (2021) and Baur et al. (2021). The theoretical background behind the nexus between gold price and gold mining stock performance is simple and straightforward. Valuation of equity is a function of promised future cashflows discounted at the cost of capital. The former has a direct tie to the commodity price and the latter is a function of the investment riskiness as viewed by the investor. A modified version of the discounted cash flow model takes into consideration the value of real options available to mining companies represented in the discretion to open, close, contract and expand mines, and adjusts the valuation accordingly (Brennan & Schwartz 1985).

The performance of gold mining stock varied over the past 25 years, from the end of February 1997 to the end of February 2022. The selected time period includes several market shocks which affected the

commodity price (collapse of the dotcom bubble, the 2008 Global Financial Crisis, commodity boom and bust, the European Debt Crisis, the US 2017 Tax Cut and Jobs Act and the COVID-19 pandemic). The selected time period excludes post-COVID-19 and the war in Ukraine due to their recency and the limited published literature on their effects. Figure 1 shows a comparison among performances of the gold spot price, gold mining stock represented by NYSE Arca Gold BUGS (HUI) index and the equity market in general, represented by the S&P500 index. The HUI index components are 24 of the world's largest and most traded gold producers, including Newmont, Barrick, AngloGold, Kinross, Gold Fields, Agnico Eagle, Harmony and Yamana, in addition to leading royalty and streaming companies including Franco Nevada, Royal Gold, Osisko, Wheaton, Sandstorm and Seabridge.

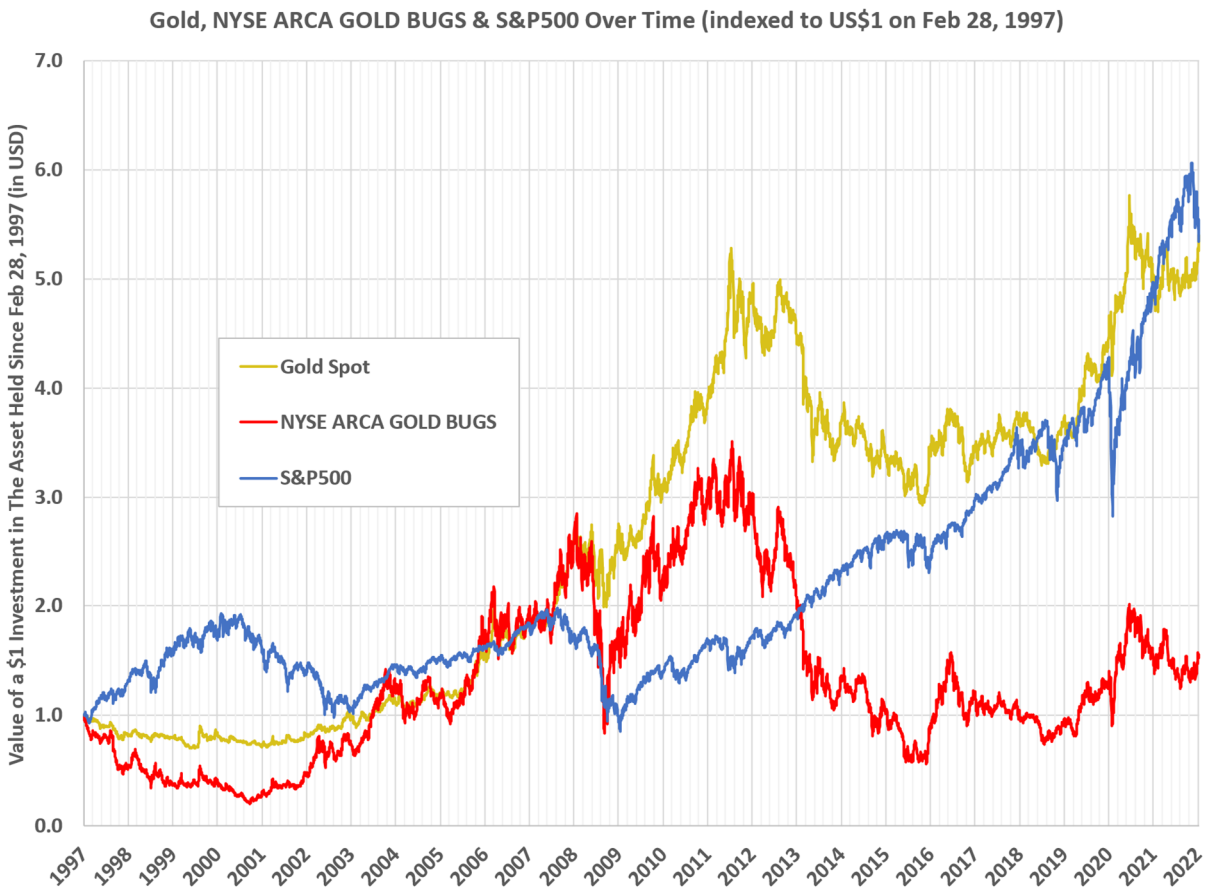


Figure 1 Performance of gold, NYSE Arca Gold BUGS index and S&P500 stock index in USD over 25 years. Graph by author. Source of data for graph: S&P 2022

Gold and the market comoved in varying patterns but were tied with a negative correlation most of the time, which supports the notion of gold being a hedger. Gold stock mostly followed gold, with a varying strength of correlation. In general, gold stock always correlated positively and strongly with gold, but with a continuous shifting of the relationship downwards, to the right and with a declining slope (or beta) as shown in Figure 2.

One possible explanation for this trend is the heightened level of mergers and acquisitions (M&A) activities within the gold mining industry, which resulted in high debt levels on the miners' balance sheets and hence increased riskiness of investment in their equities. Given the activist nature of institutional investors and the level of holdings they always had in gold mining companies, their protest of M&A transactions (exiting in herds) drove stock prices down (De Los Reyes 2017).

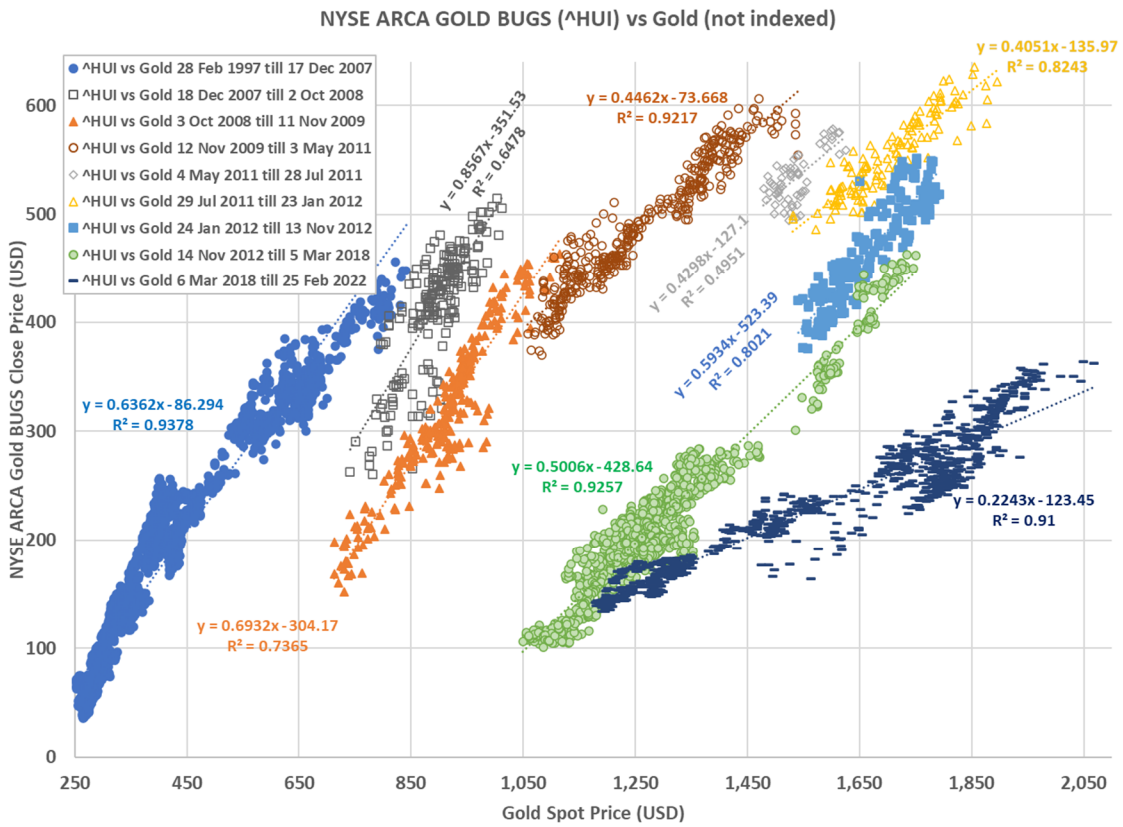


Figure 2 NYSE Arca Gold BUGS index versus gold price over 25 years. Graph by author. Source of data for graph: S&P 2022

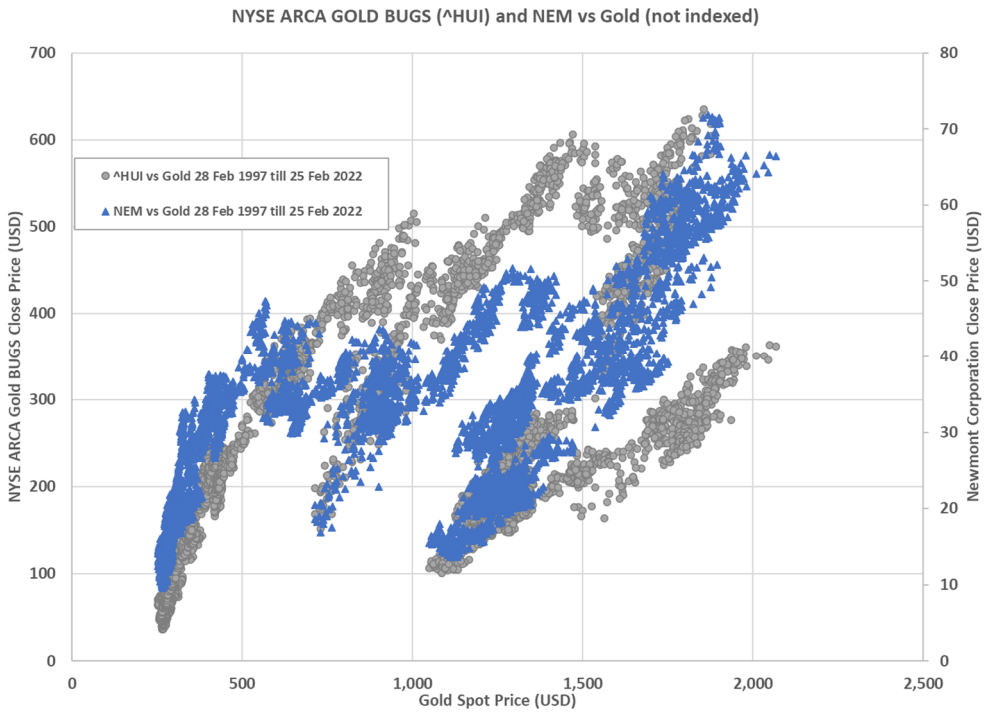
Institutional investors have been increasing their focus on environmental, social and governance (ESG) issues in the last decade. In 2015 the signatories to the United Nations-supported Principles for Responsible Investing Initiative included 1,400 institutions representing assets under management (AUM) worth USD 59 trillion (Chen & Lin 2020). In September 2022 there were 5,179 signatories, representing USD 121 trillion worth of AUM (United Nations 2022). This could offer an opportunity to gold mining companies to create better alignment with institutional investors' investment criteria by improving their ESG performance.

This paper explores the environmental pillar of ESG, especially as it relates to mine tailings management and the potential to enhance the attratctiveness of gold mining equities to institutional investors. The first section discusses the relationship between environmental performance and stock performance. The second section discusses the relationship between different aspects of mine tailings management methods (such as water use, waste generation and land use) and environmental performance. The third section consolidates findings from previous sections to demonstrate the relationship between improvements on environmental metrics via the selection of a tailings management method and potential improvement on stock performance. Finally, the conclusion section provides recommendations to mine waste practictioners, and identifies the gaps that still exist and the opportunities for future research in the area.

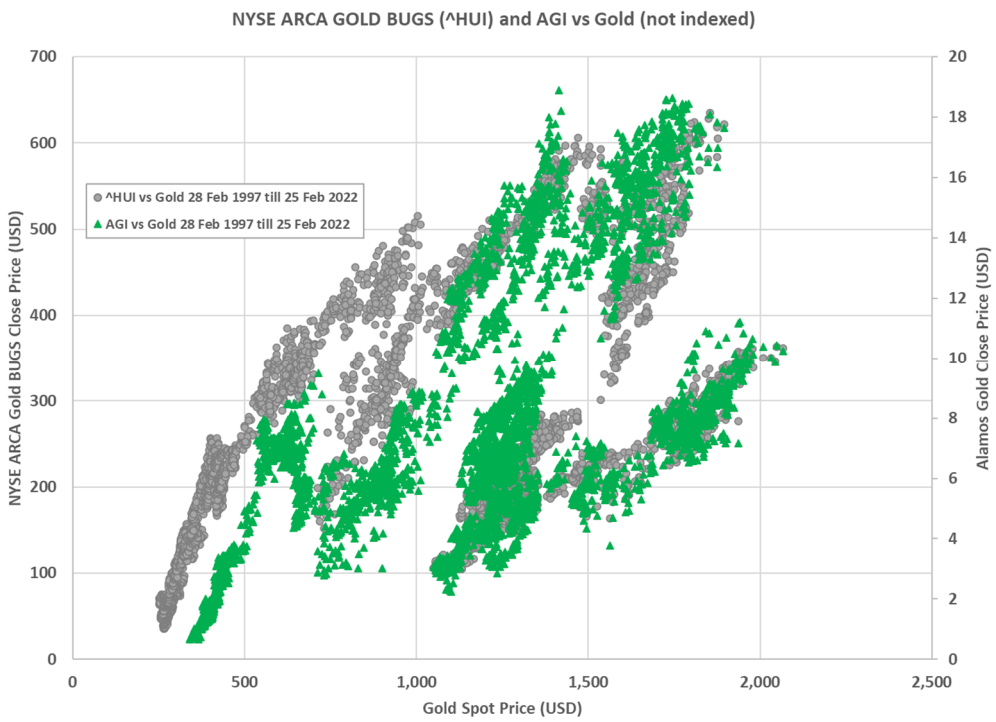
2 Environmental pillar ESG score and stock performance

A sample of 42 gold mining companies was studied: Newmont, Barrick, Agnico Eagle, Newcrest, Gold Fields, Northern Star, AngloGold, Endeavour, Kinross, B2Gold, Freeport, SSR Mining, Alamos, Evolution Mining, Lundin Gold, First Quantum, NovaGold, Perseus, Hecla, Harmony Gold, K92 Mining, Centamin, OceanaGold, Eldorado, Pan American Silver, Equinox, Centerra, Yamana, Wesdome, Coeur, Regis Resources, Resolute Mining, Buenaventura, New Gold, Torex, IAMGOLD, Hochschild, DRDGOLD, Aura Minerals, St Barbara, Pan African Resources and Victoria Gold. These companies are listed on major stock exchanges (NYSE, TSX, LSE, and ASX) and represent close to 50% of the global mining industry in terms of market capitalisation and gold

production (S&P 2022). The stock performance of each company was compared to the performance of the HUI index in terms of the shift in the relationship with the gold commodity spot price over the past 25-year period. The performance was classified into three categories: outperforming (Figure 3A), at par (Figure 3B), and underperforming (Figure 3C). Out of the 42 companies, nine companies' stocks were found to be outperforming the index. In other words, the downward, rightward and declining slope shift in the relationship between the stock price and the gold spot price was less than it was for the HUI index. The stocks of 12 companies were at par with the index, and stocks of 21 companies were found to be underperforming the index. These results are summarised in Table 1.



(a)



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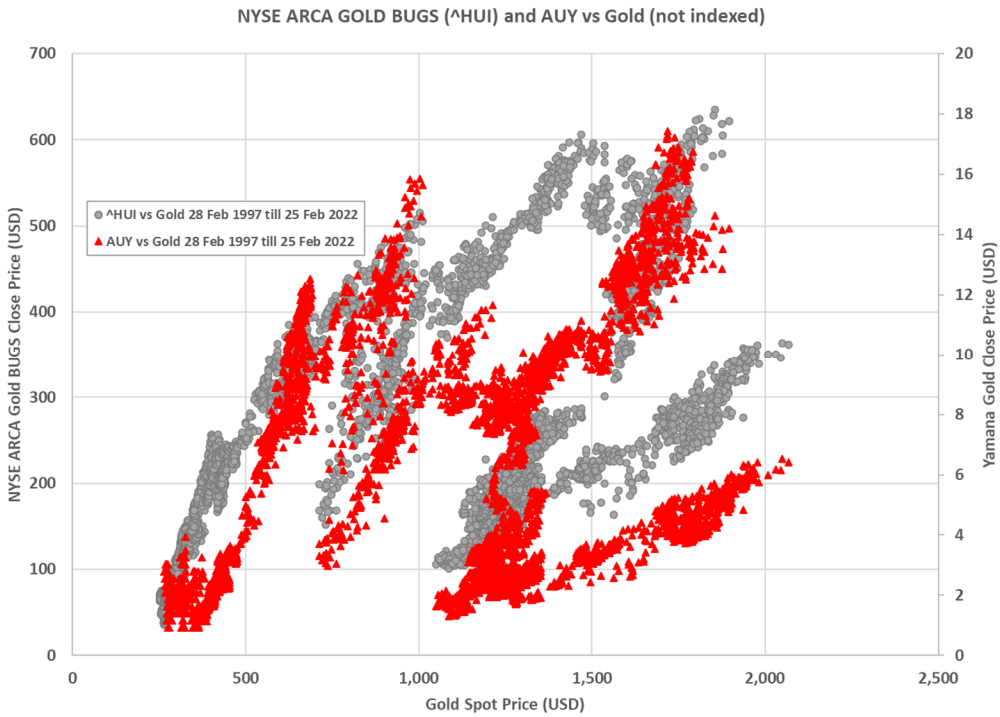

(c)

Figure 3 (a) Example of stock outperforming the HUI index in terms of the shift in the relationship with the gold spot price; (b) Example of stock at par with the HUI index in terms of the shift in the relationship with the gold spot price; (c) Example of stock underperforming the HUI index in terms of the shift in the relationship with gold spot price

The environmental pillar ESG scores for the companies within the sample were studied. It was observed that the history and establishment of ESG data disclosure varied significantly among the 42 companies. For example, some companies disclosed ESG scores for the past two years while others disclosed ESG scores for the past 18 years. Ten out of the 42 companies disclosed ESG scores for the last 12–13 years. In general, the environmental pillar ESG scores trended up for most of the companies within the sample. In order to account for the establishment of the ESG score disclosure, the companies' ESG performances were measured based on the summation of their scores over the past 18 years. The classification into three categories was based on comparison of each company's summation of ESG scores to the terciles of all 42 summations.

The 42 companies' environmental pillar ESG score performances were paired with their corresponding stock performance categories, as shown in Table 1.

Table 1 Observed data for stocks performance and environmental pillar ESG scores performance

		Stock performance relative to HUI index			
		Outperforming	**At par**	**Underperforming**	**Subtotals**
Environmental pillar ESG score performance terciles	Upper tercile	6	3	5	14
	Middle tercile	2	7	5	14
	Lower tercile	1	2	11	14
	Subtotals	9	12	21	
	Total				42

To test the association between environmental pillar ESG scores and stock performances, a chi-squared test was performed with a null hypothesis that there is no association between environmental pillar ESG scores and stock performances. Using the observed data in Table 1, the chi-squared statistic is calculated as 6.8571 with two degrees of freedom. The calculation of the chi-squared statistic requires combining adjacent categories if any of the expected values (calculated by dividing the multiple of raw subtotal and column subtotal by the total number of observations) are less than five. Since the calculated statistic lies well within the 5% tail of the chi-squared distribution with two degrees of freedom (critical value is 5.9915), the null hypothesis can be rejected at the 5% level of significance.

While acknowledging that association does not necessarily mean correlation or causation, this result makes intuitive sense given the influence institutional investors have on gold mining stock and their emphasis on ESG in recent years, as discussed in previous sections.

3 Mine tailings management options and their impact on ESG metrics

Mining operations generate waste primarily in the form of waste rock and tailings. The focus of this paper is on tailings. The method adopted for tailings management has direct impacts on the metrics used to calculate the environmental pillar of the ESG score. Water use is directly tied to the tailings management method as the water content of the tailings is the major parameter that defines each one of these tailings management methods. Total waste is tied to whether the mine site's tailings management method involves recycling of part of the tailings by using it in underground backfilling. Finally, land use is directly tied to the footprint occupied by tailings, which is tied to the tailings management method.

3.1 Water use

Performance of different mine tailings management methods in terms of reducing the environmental footprint by increasing water efficiency, improving mine closure effectiveness, and reducing dam failure risk to the environment and communities, has been studied extensively. In a report to the Mine Environment Neutral Drainage program, Klohn Crippen Berger (2017) compared the four dominant tailings management methods (conventional slurry, thickened, paste and filtered tailings) in terms of their effectiveness in reducing water losses and hence net fresh water draw. The report included case studies on 53 mine sites in different climatic conditions that influenced the decision to adopt tailings management methods to suit the water balance situations. Figure 4 provides an overview of the methods selected at these sites.

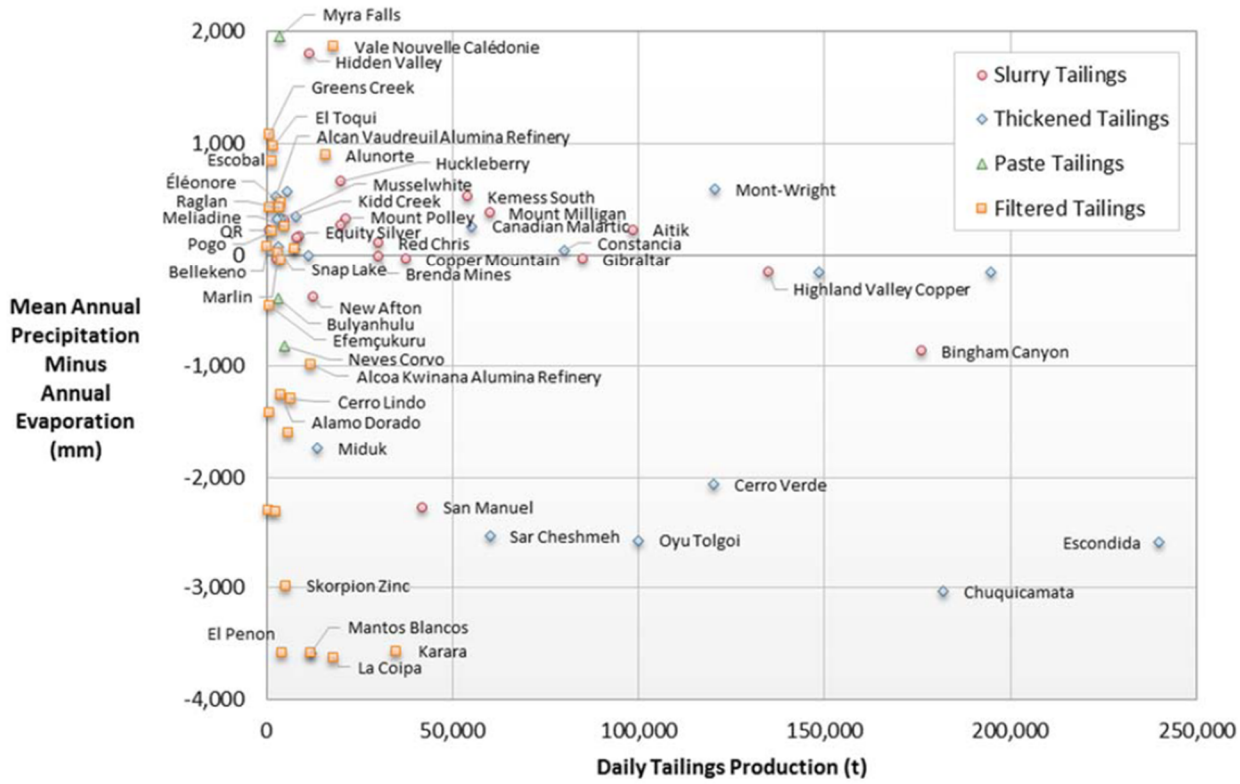

Figure 4 Daily tailings production, site precipitation-evaporation balance and choice of tailings management method (Klohn Crippen Berger 2017)

Filtered tailings are dominant in dry conditions, testifying to this method's effectiveness in preserving water. Out of 31 sites with negative precipitation-evaporation balance, 14 apply filtered tailings, two apply paste tailings, eight apply thickened tailings and only seven apply conventional slurry tailings. Out of 19 sites with –1,000 mm or below precipitation-evaporation balance, 12 apply filtered tailings, six apply thickened tailings and only one applies conventional slurry tailings.

Each method's water efficiency is directly tied to the content of water in the tailings and hence the potential of water losses to evaporation and seepage. Filtered tailings have an added advantage of slightly reducing the portion of water entrained in tailings when compared to the other three methods. Figure 5 illustrates this concept. The figure also demonstrates the superiority of non-conventional methods in enabling progressive closure.

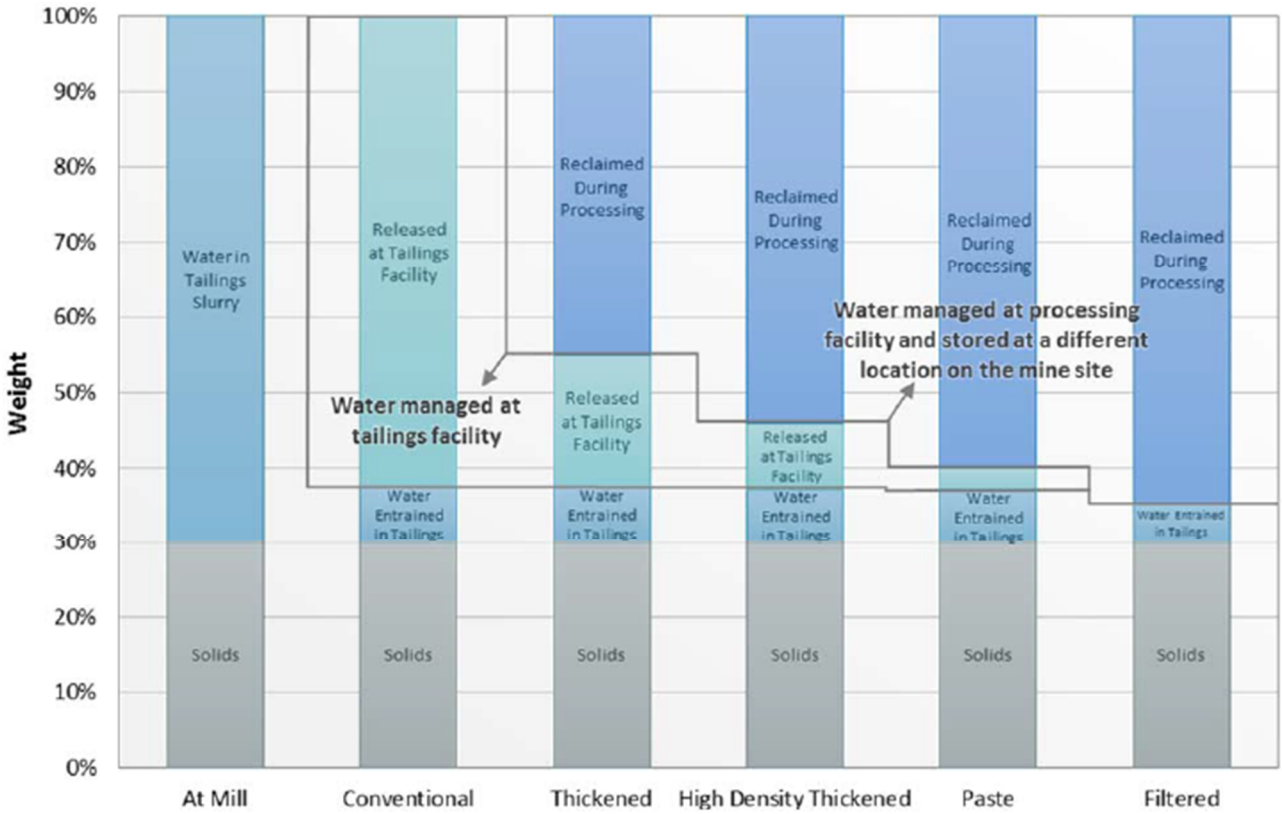

Figure 5 Tailings management methods and tailings water content (Klohn Crippen Berger 2017)

Quantifying the water savings associated with each tailings management method must be site specific as most of the losses are caused by evaporation which is dependent on the climatic conditions at the site's geographic location. However, water efficiency is directly tied to the amount of water at risk, which is equivalent to the water content in tailings. Watson et al. (2010) provided a general comparison among different tailings management methods in terms of water recovery efficiency, as shown in Table 2.

Table 2 Comparison among tailings management methods in terms of water recovery efficiency

Tailings management method	Typical percent water recovery
Conventional slurry disposal	50–60
Thickened tailings disposal	60–70
Paste tailings disposal	80–90
Filtered tailings disposal	>90

Adopting alternative tailings management methods has the potential to improve water efficiency by approximately 18, 55 and 67% for thickened, paste and filtered tailings disposal, respectively, over conventional slurry disposal.

The same sample of 42 gold mining companies discussed previously was studied to assess the association between water use performance and the environmental pillar of the ESG score. For each company, the water use in cubic metres per million USD revenue performance metric, and the environmental pillar of the ESG score as reported for each year over an 18-year period, were paired, resulting in 269 pairs. Reporting ESG and related metrics varied from one company to the other within the 42 companies' sample as mentioned in previous sections. The water use data were classified into three categories based on the relationship of each piece of data to the upper tercile (below 9,254 cubic metres per million USD revenue), middle tercile

(between 9,254 and 17,672 cubic metres per million USD revenue) and lower tercile (above 17,672 cubic metres per million USD revenue).

The same was applied to the environmental pillar of the ESG scores. The data were classified into three categories based on the relationship of each piece of data to the upper tercile (environmental pillar ESG score above 73.65), middle tercile (environmental pillar ESG score between 73.65 and 59) and lower tercile (environmental pillar ESG score below 59). The observed data for the water use metric and environmental ESG scores are illustrated in Table 3.

Table 3 Observed data for water use and environmental pillar ESG scores performances

		Water use (cu.m per USD revenue) performance			
		Upper tercile	**Middle tercile**	**Lower tercile**	**Subtotals**
Environmental pillar ESG score performance terciles	Upper tercile	35	23	32	90
	Middle tercile	25	42	22	89
	Lower tercile	30	24	36	90
	Subtotals	90	89	90	
	Total				269

To test the association between environmental pillar ESG scores and stock performances, a chi-squared test was performed with a null hypothesis that there is no association between water use performance and the environmental pillar ESG score. Using the observed data in Table 3, the chi-squared statistic is calculated as 12.8768 with four degrees of freedom. Since the calculated statistic lies well within the 5% tail of the chi-squared distribution with four degrees of freedom (critical value is 9.4877), the null hypothesis can be rejected at the 5% level of significance. This means that there is a strong association between a lower water usage and achievement of a higher environmental pillar ESG score.

3.2 Total waste

Use of tailings as an ingredient in underground mine backfilling was first implemented in 1979. The practice started to gain significant ground and was extended to include disposal of mine waste in spent open pits during and after the 1990s (Qi & Fourie 2019). The tailings used in backfill reduces the amount of generated mine waste. The backfill has the potential to consume 60–75% of the tailings (Lu et al. 2018). The extent of reduction in total waste by the use of tailings in backfill of either underground stopes or spent open pits is site specific as it depends on the method, schedule and sequence of the mining operations. However, despite the fact that falling within the 60–75% range may not be acheivable in many cases, it is fair to say that these reductions are significant in general.

The same sample of 42 gold mining companies discussed previously was studied to assess the association between total waste performance and the environmental pillar of the ESG score. For each company, the total waste in metric tonnes per million USD revenue performance metric and the environmental pillar of the ESG score as reported for each year over an 18-year period, resulting in 269 pairs. The total waste data were classified into three categories based on the relationship of each piece of data to the upper tercile (below 32,247 metric tonnes per million USD revenue), middle tercile (between 32,247 and 68,782 metric tonnes per million USD revenue) and lower terciles (above 68,782 metric tonnes per million USD revenue).

The same was applied to the environmental pillar of the ESG scores as described in previous sections. The observed data for the total waste metric and environmental ESG scores are illustrated in Table 4.

Table 4 Observed data for total waste and environmental pillar ESG scores performances

		Total waste (metric tonnes per USD revenue) performance			
		Upper tercile	**Middle tercile**	**Lower tercile**	**Subtotals**
Environmental pillar ESG score performance terciles	Upper tercile	45	18	27	90
	Middle tercile	24	29	36	89
	Lower tercile	21	42	27	90
	Subtotals	90	89	90	
	Total				269

To test the association between total waste metrics and environmental pillar ESG scores performances, a chi-squared test was performed with a null hypothesis that there is no association between total waste performance and the environmental pillar ESG score. Using the observed data in Table 4, the chi-squared statistic is calculated as 22.8650 with four degrees of freedom. Since the calculated statistic lies well within the 5% tail of the chi-squared distribution with four degrees of freedom (critical value is 9.4877), the null hypothesis can be rejected at the 5% level of significance. This means that there is a strong association between a lower total waste generation and achievement of a higher environmental pillar ESG score.

3.3 Other metrics

Other metrics related to the environmental pillar of the ESG score were not studied in this paper. These metrics include land use, energy use and carbon dioxide emission, among many others. Land use is usually coupled with biodiversity and provided in categorical format. It was not possible to obtain metrics in continuous numerical format for the purposes of this paper. However, land use is directly tied to total waste and the tailings management method as less water content in the tailings improves the space efficiency of the tailings deposition.

Energy use associated with alternative tailings management methods is likely to be higher than it is for conventional tailings. Energy use has a negative impact on the environmental pillar ESG score. Whether this negative impact is outweighed by the positive impacts of reduced water use, total waste and land use is an opportunity for future research to uncover.

Carbon dioxide emission is tied to energy use and the extent of green energy within the overall energy mix. Hence, it is likely to have a similar effect as energy use on the ESG score. However, recent research on use of mine tailings for carbon sequestration is promising (Grasa et al. 2020; Siegrist et al. 2017; Power at al. 2014). Chen et al. (2022) conclude that each tonne of cemented paste backfill "can absorb about 78.4 kg CO_2 within 28 days, which is equivalent to treating 2,600 m^3 of dirty air in the mined-out stopes under ideal conditions" (Chen et al. 2022, p. 9).

4 Mine tailings management and financial performance

Mine tailings management options are usually evaluated on a lifecycle cost basis using a discounted cash flow model. The discount rate is usually determined based on the company's cost of capital. Other benefits that do not have direct and clear financial quantification are usually measured on a qualitative scale. The previous sections have demonstrated that the environmental aspects of the considered mine tailings management option can have a direct and quantifiable impact on the company's finances which, in turn, adjusts the cost of capital and hence affects the economic evaluation of the option.

The association between ESG scores and stock performance for gold mining companies is evident and agrees with the notions of institutional investors' emphasis on ESG and their weight in gold mining equities ownership.

Adopting a tailings management method as an alternative to conventional slurry deposition can significantly reduce water use by an order of magnitude in the case of filtered tailings deposition. As seen in the 42 gold mining companies sample studied in this paper, the boundary between the middle and lower terciles for water use is 17,672 cubic metres per million USD revenue. The boundary between the middle and upper terciles for water use is 9,254 cubic metres per million USD revenue. Reducing water use by 50% is well within reach, especially if paste or filtered tailings methods are adopted. This has the potential to move the mining company across the terciles.

Use of tailings to make paste for backfill of underground stopes or spent open pits can significantly reduce the total waste. Both metrics (water use and total waste) are strongly associated with the ESG score, which is becoming an important investment criteria for institutional investors (Chen at al. 2020). As seen in the 42 gold mining companies sample studied in this paper, the boundary between the middle and lower terciles for total waste is 68,782 metric tonnes per million USD revenue. The boundary between the middle and upper terciles for total waste is 32,247 metric tonnes per million USD revenue. Reducing total waste by 40% is well within reach if tailings are used for paste backfill of underground stopes or spent open pits. This has the potential to move the mining company across the terciles.

Other ESG-related aspects not discussed in this paper will be taken in consideration. The increase in energy use associated with tailings management methods other than the conventional is likely to counter, but not necessarily outweigh, the benefits promised by improvements on other metrics. The reduction in land use associated with tailings that have better space efficiency due to higher density and better physical characteristics is worthy of consideration. Opportunities exist for future research that explores and incorporates these aspects.

Finally, the focus in this paper has been on the environmental pillar of ESG due to its relevance to mine waste. Other ESG aspects are still worthy of consideration. For example, reducing the risk of catastrophic tailings dams failures and reduction in land use can be directly, and possibly quantitatively, tied to improvements in the social and governance pillars of ESG. The focus of the paper is on aspects that have direct, more immediate and more quantifiable potential impact on ESG scores. Other aspects that are related to long-term sustainability and are more qualitative by nature are equally important. Opportunities exist for future research that explores these aspects and yields results that enable quantification of their impact on ESG scores.

5 Conclusion

The gold mining industry is unique due to the uniqueness of the commodity it produces. Investors' motives for investing in gold mining equity are very similar to their motives for investing in gold coins, bullion and ETFs: diversification and hedging of their portfolios. This results in a higher-than-average ownership by institutional investors in gold mining companies, which poses a challenge but also offers an opportunity. Gold mining companies can take advantage of this opportunity of heightened emphasis on ESG issues by institutional investors. This paper has shown a direct line of sight between alternative tailings management methods and the benefits they offer in terms of reduced water use and reduced total waste, and alignment with institutional investors' investment criteria. This should encourage these influential investors to maintain their positions which, in turn, will maintain strong stock performance; hence reducing the cost of capital to the gold mining company.

Operations and mine tailings practitioners are encouraged to add the following steps to their tailings management options evaluation procedure:

- Engage ESG professionals either from the organisation or specialised consultants.
- Engage corporate finance professionals who have good insights into major shareholders' criteria.
- Establish a model, in an as quantitative as possible form, for the relationship between ESG performance and stock performance.

- Establish a tie between the attributes of each tailings management option and ESG metrics.
- Establish cost of capital values estimated in light of the points above for each tailings management option for use in the economic evaluation of the option.
- Run analysis to test the sensitivity of decision-driving parameters to assumptions.

This paper is a humble step along the way to creating a definitive model for the relationship between ESG issues and the financial performance of gold mining companies. Opportunities for future research in the area include:

- Use of a larger sample of gold mining companies to enable the performing of other types of statistical analysis such as quantile, linear and non-linear regressions.
- Consideration of more variables representing metrics that affect ESG scores and of the possible correlations among them in order to identify and eliminate potential data bias.
- Incorporation of the aspects that were not covered in this paper, such as land use, power use and carbon dioxide emission, including opportunities for carbon sequestration.
- Incorporation of other mine waste aspects like co-disposal of waste rock and tailings into the evaluation model.

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